ORIGINS

The Search for Our Cosmic Roots

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[illegible]

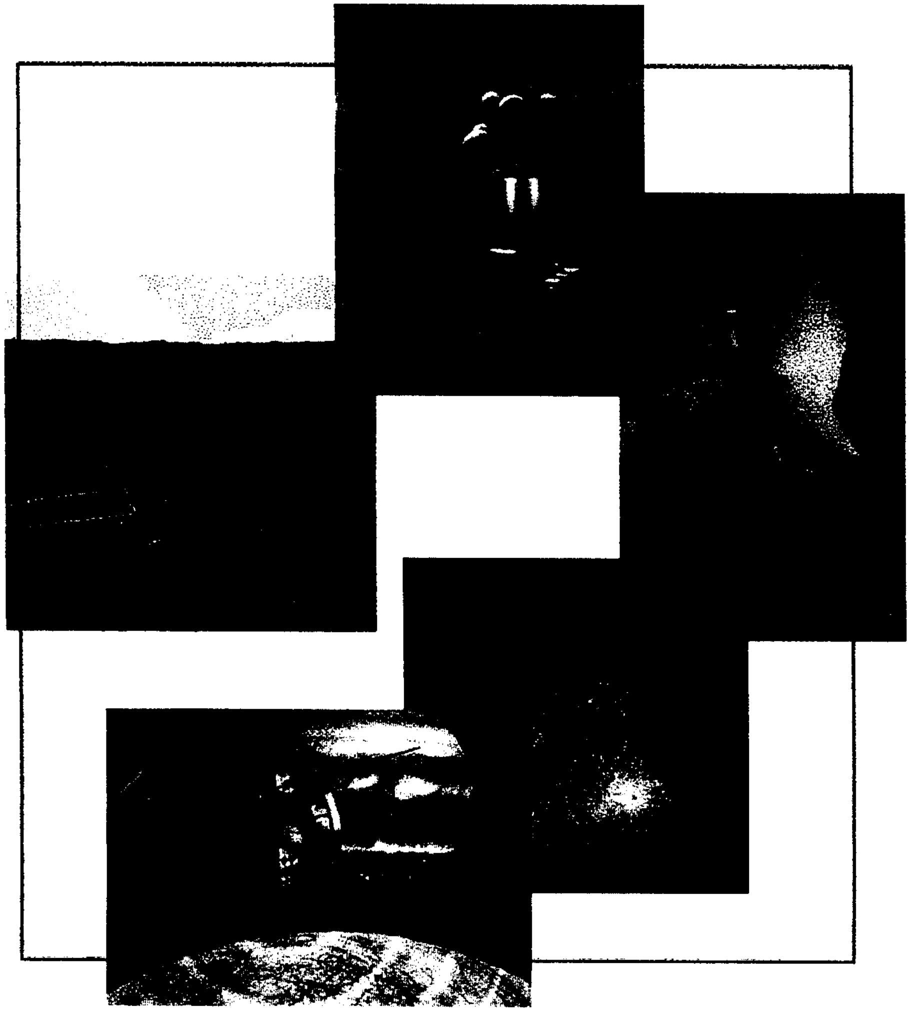
Three millennia later when we think of the ancient Egyptians, we associate them with building the great pyramids.

A millennium from now what will our civilization be remembered for?

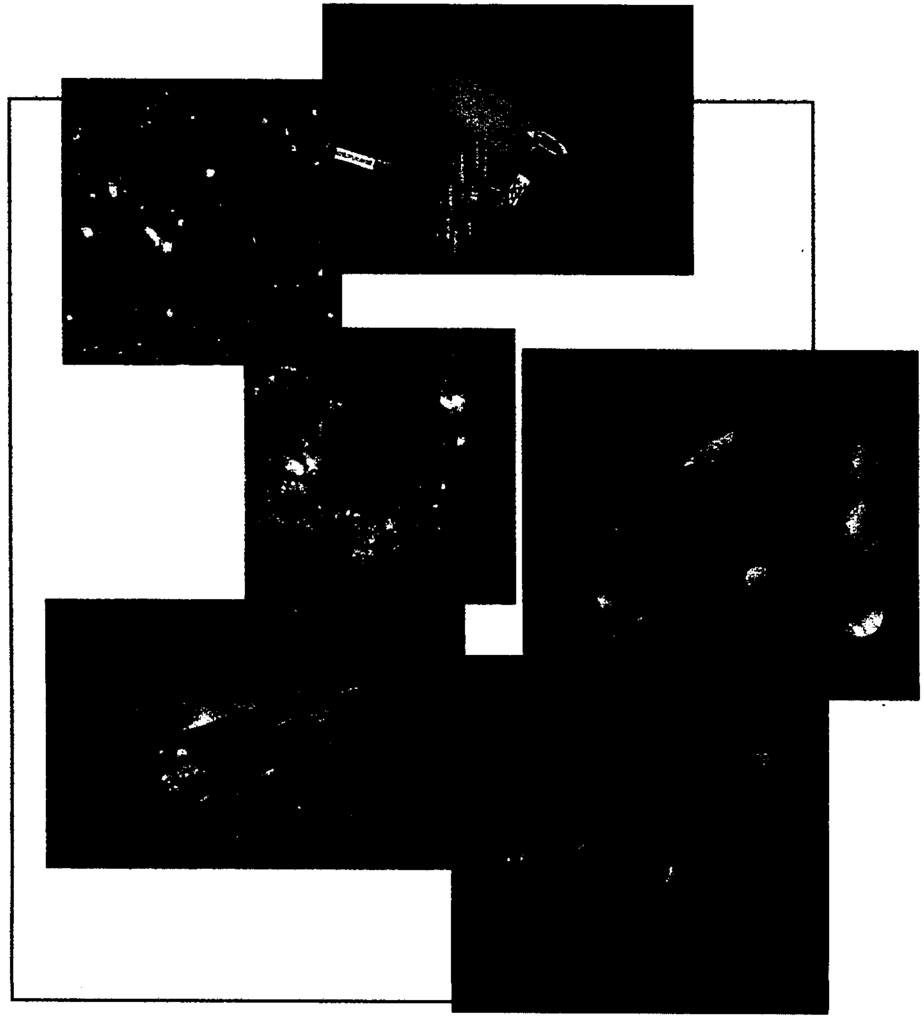

ORIGINS
Element Formation in Stars
The Big Bang
Planetary System Formation
Forming Earth-Like Planet
Chemistry of Life

Components of NASA's Origins Program

Reconnaissance and In-Situ Exploration of Our Solar System



Observation of the Universe



Characteristics of Origins Observatories

- **One or more of the following characteristics can be found in the Origins Observatories:**

Large Aperture

- **>10 times HST aperture**
- **For the sensitivity needed to see faint objects far away**
  - **First galaxies**

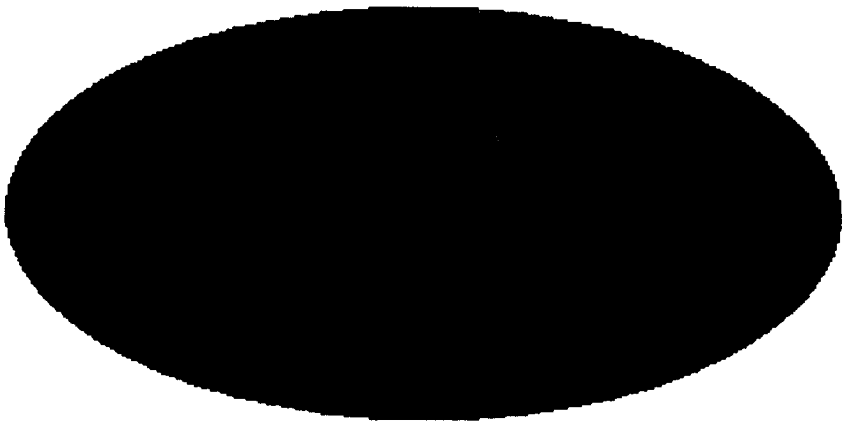
High resolution

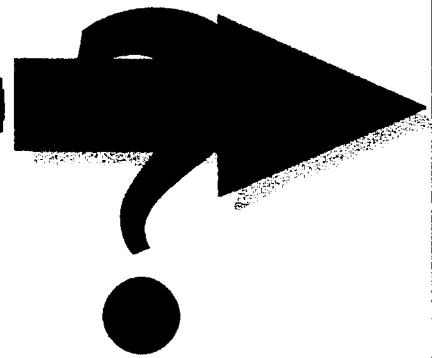
- **"Equivalent" to football-field size telescope to see small objects**
  - **Planet detection**

IR Operation

- **To see through dust clouds (SIRTF)**
- **To see high redshift galaxies (NGST)**
- **To detect planets next to bright stars (TPF)**

How Did Galaxies Form?





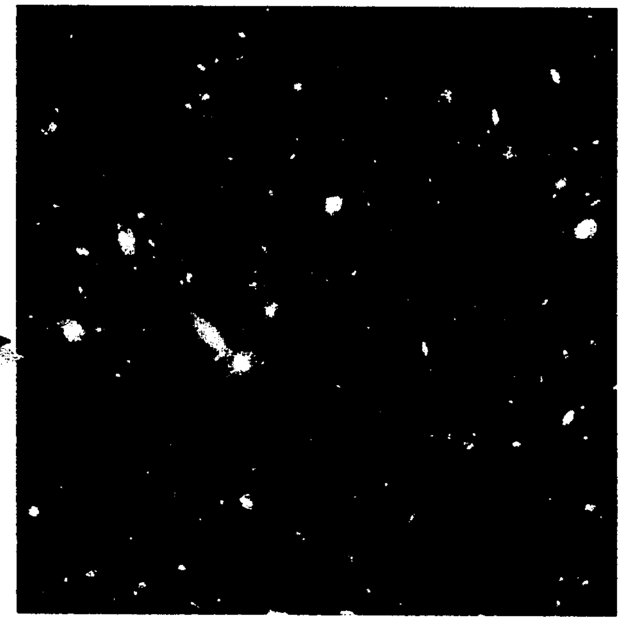
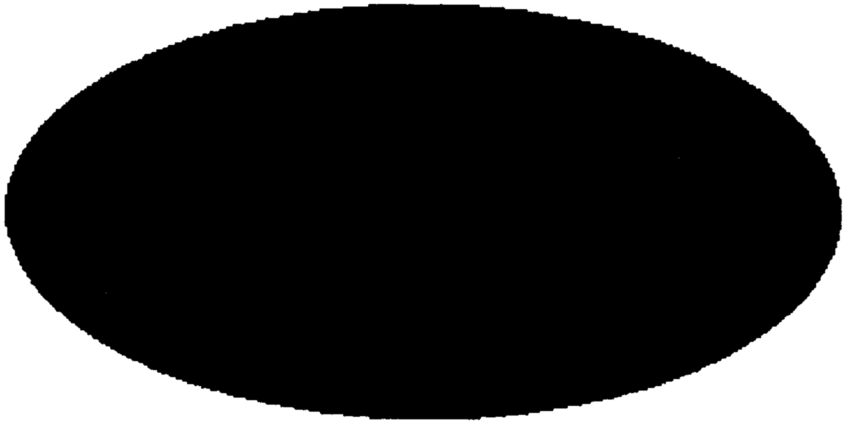


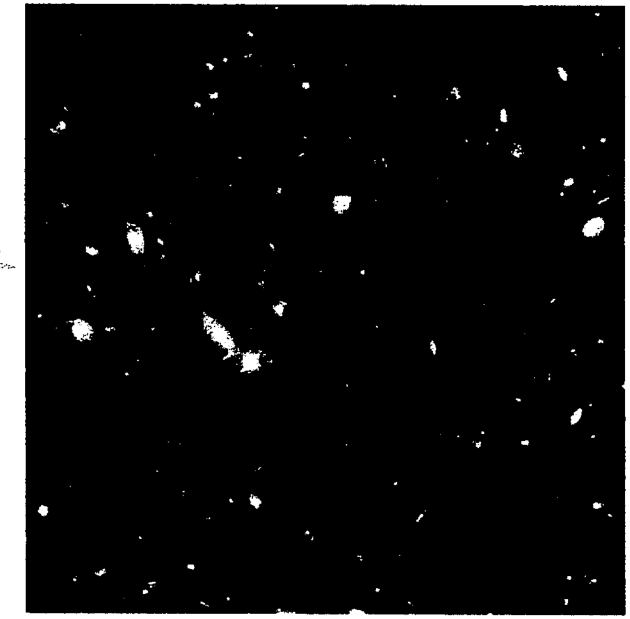
Image taken by COBE of a universe only a few million years old shows a nearly uniform universe with only subtle features – the seeds of grander structures yet to come

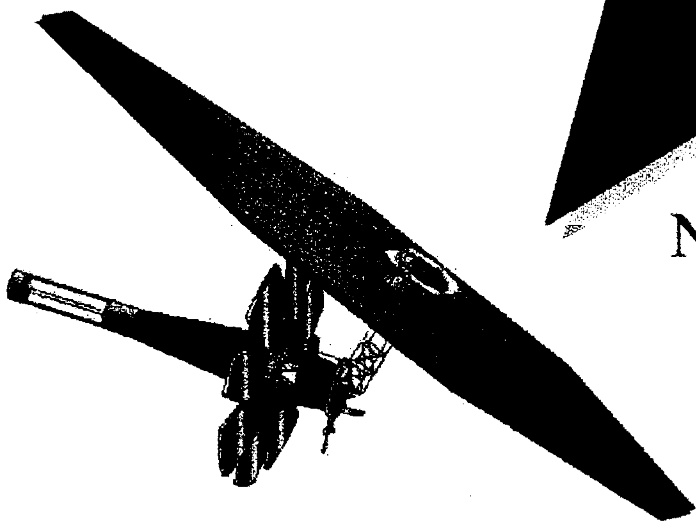
Hubble Space Telescope image peering deep into the universe to within a few billion years after its birth shows already fully-formed galaxies

Next Generation Space Telescope (NGST)

The Successor to the Legacy of the Hubble Space Telescope

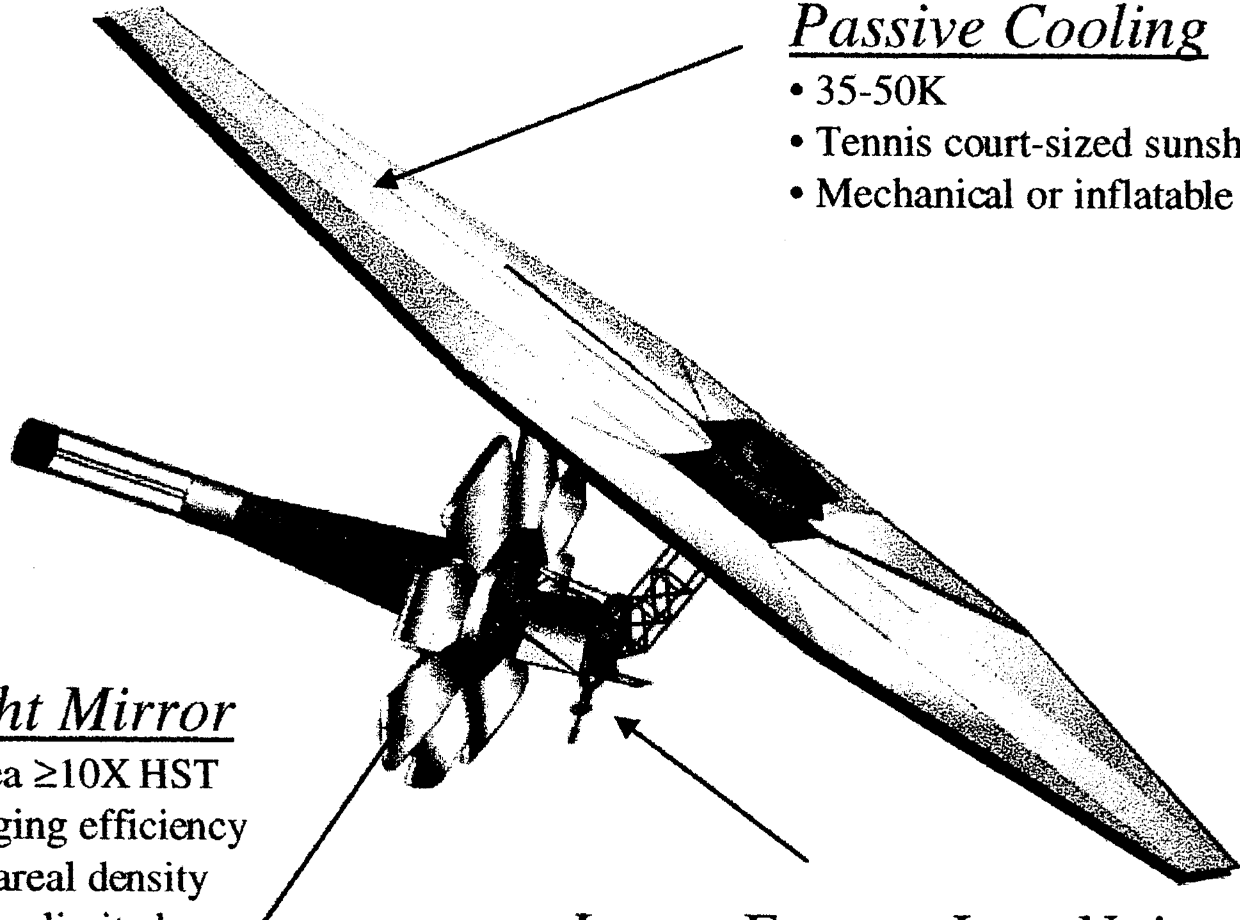






NGST – Visiting a Time When the
Galaxies Were Young

NGST Technology Challenges



Passive Cooling

- 35-50K
- Tennis court-sized sunshade
- Mechanical or inflatable deployment

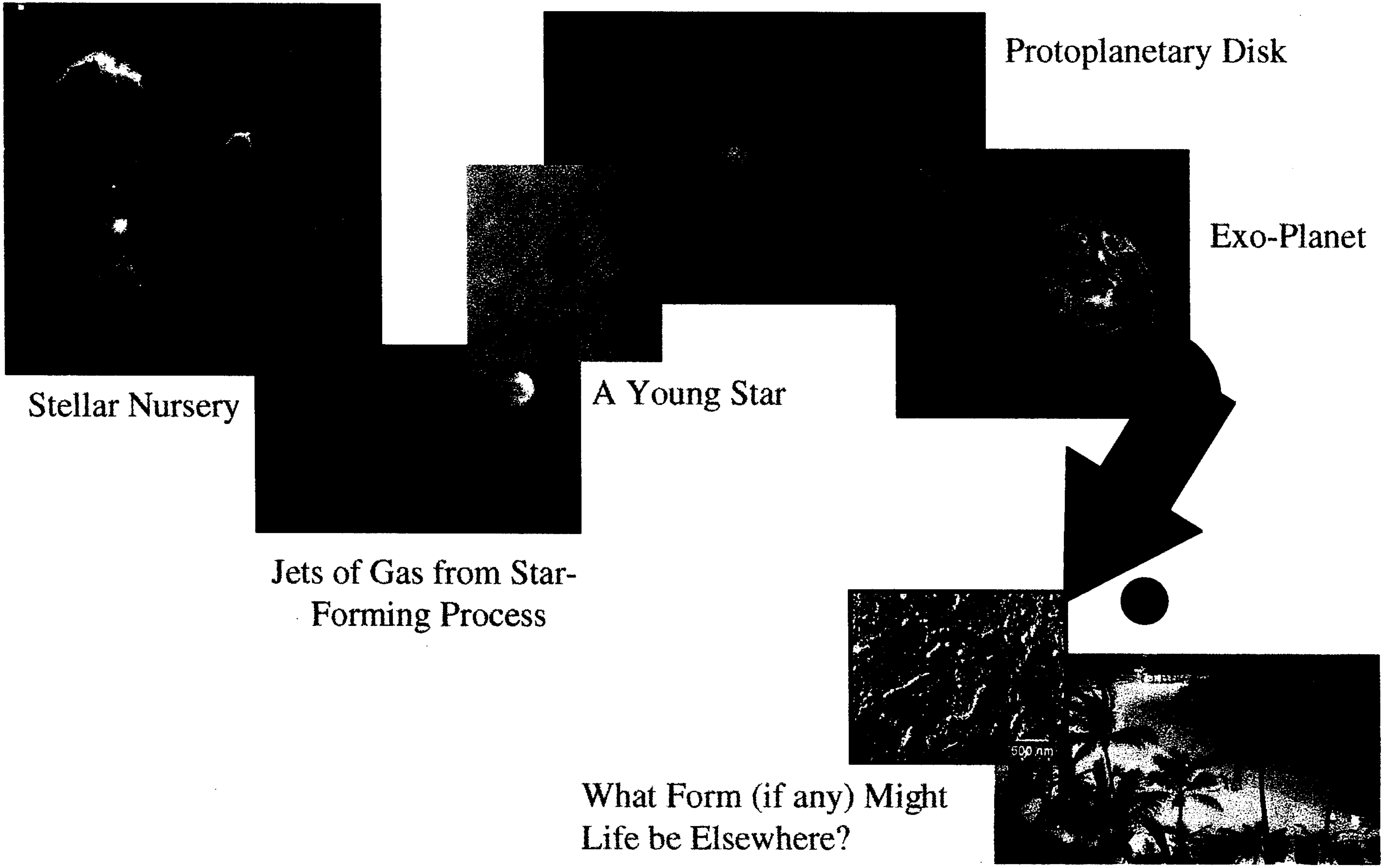
Lightweight Mirror

- Collection area ≥10X HST
  - High Packaging efficiency
- 10-15 kg/m2 areal density
- 2μm diffraction limited
  - Rigid body control (to a λ)
  - Active wavefront control to $\lambda/20$

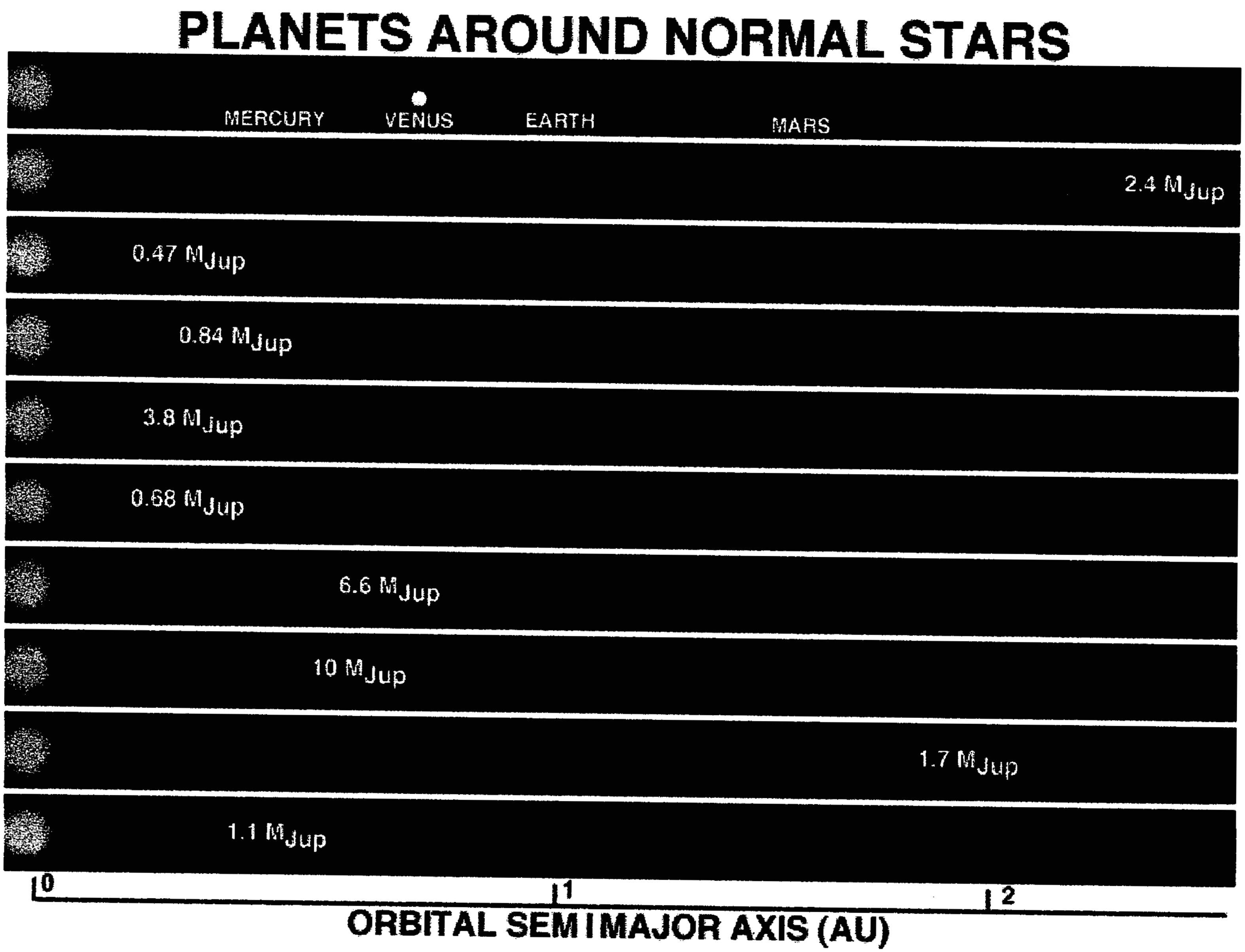
Large Format Low Noise IR Arrays

- Near IR camera & spectrometer (1-5μm)
- Thermal IR camera & spectrometer (5-20μm)

How Do Stars and Planetary Systems Form?
Are There Planets Around Other Stars That Can Sustain Life?

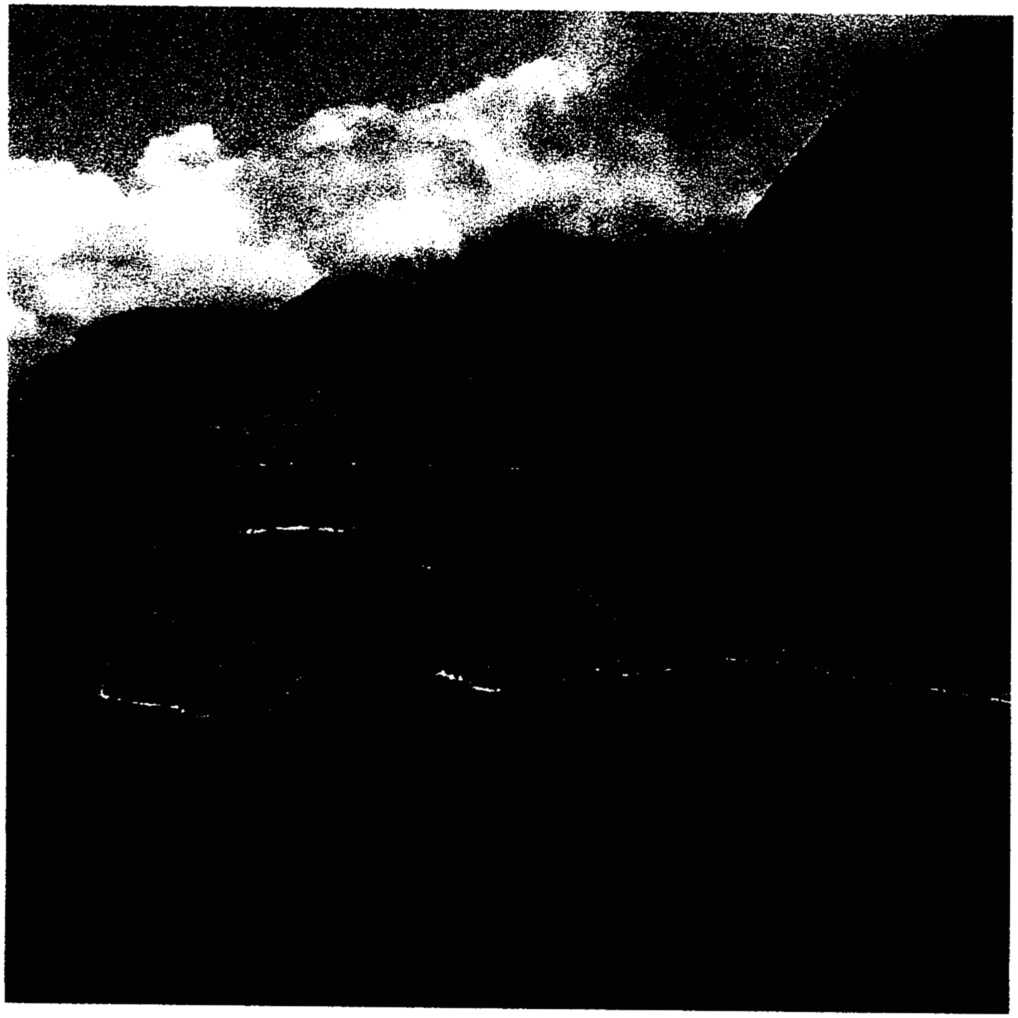


Nine Planets *not* in Our Solar System

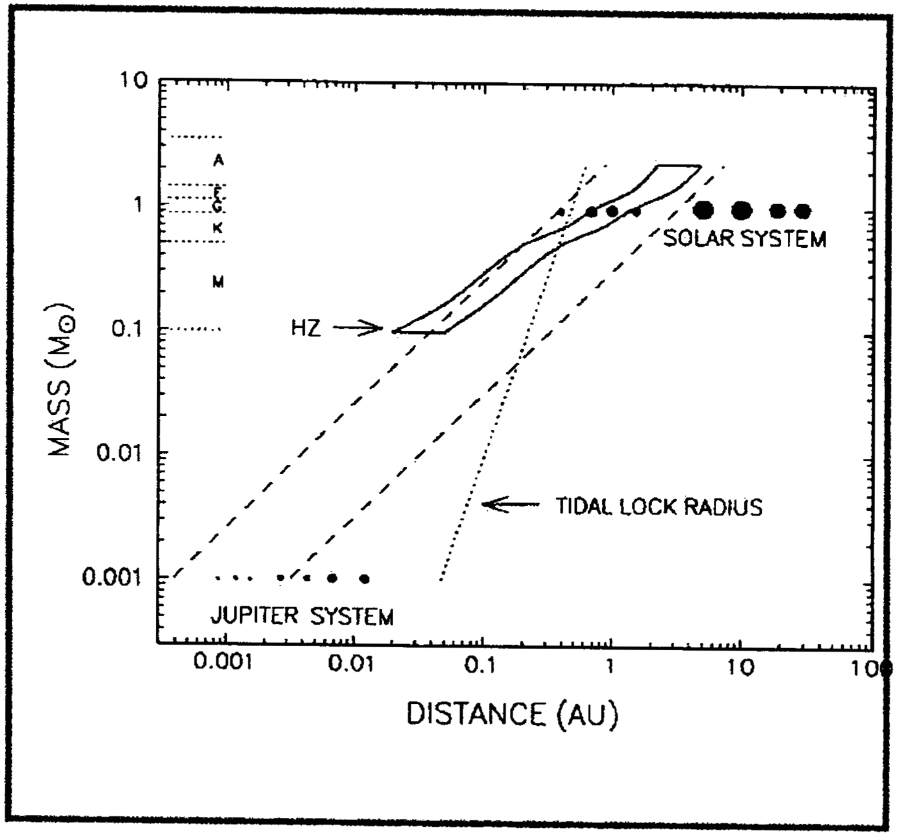


Earth-Like Planet?

This May Not Be the Paradigm

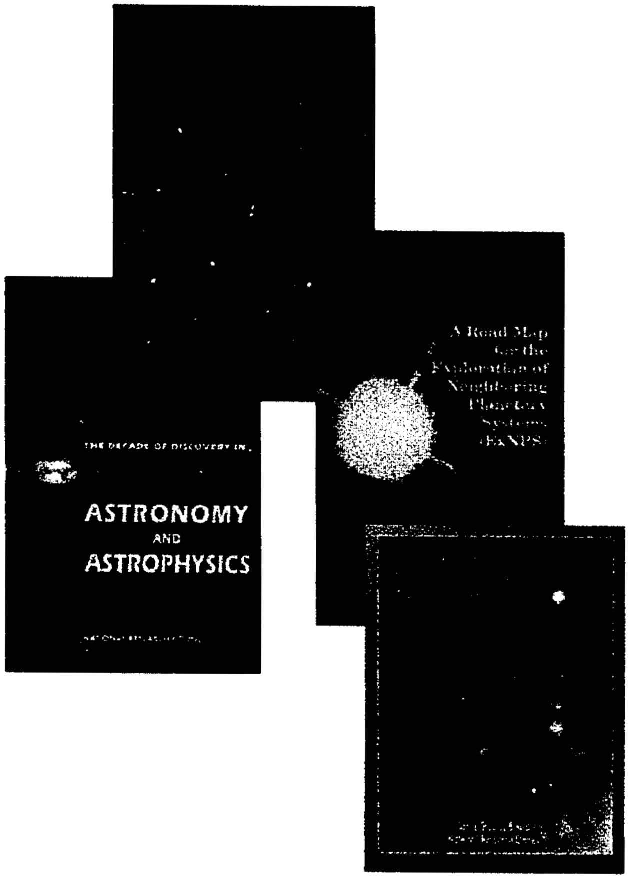


Habitable Zone

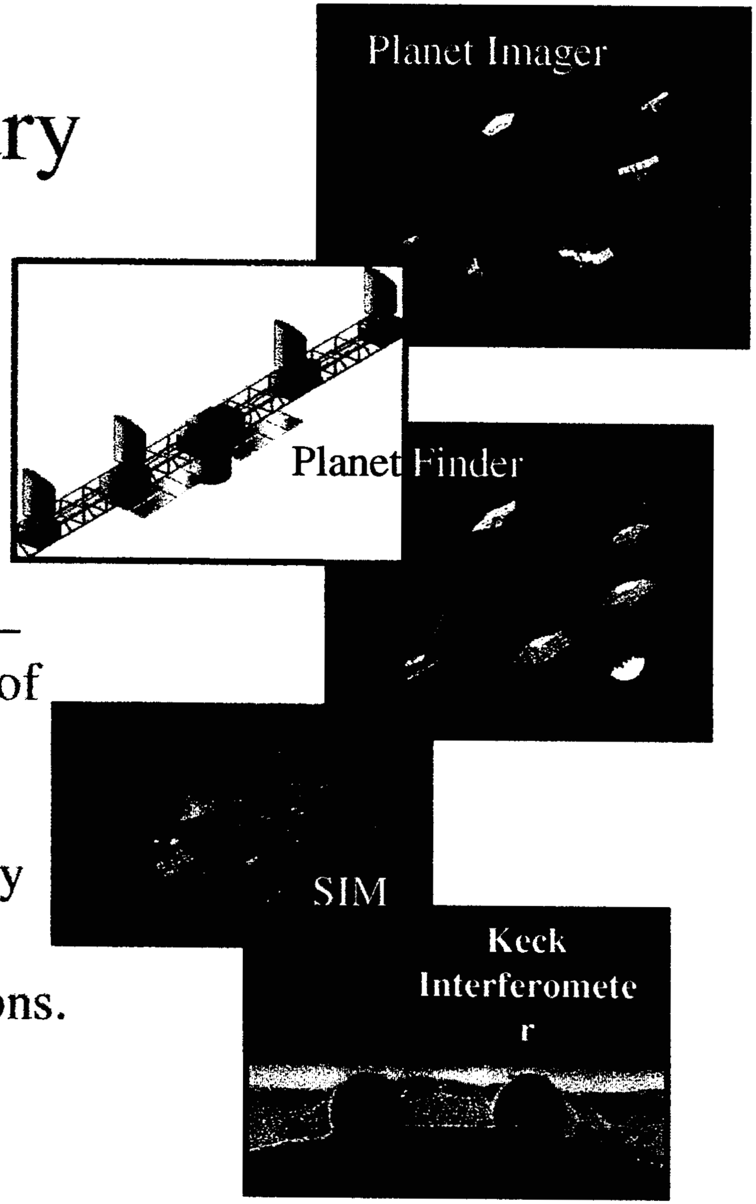


Interferometry

Most recent reports chartered by the National Academy of Sciences and others have urged NASA to develop and fly interferometer observatories.

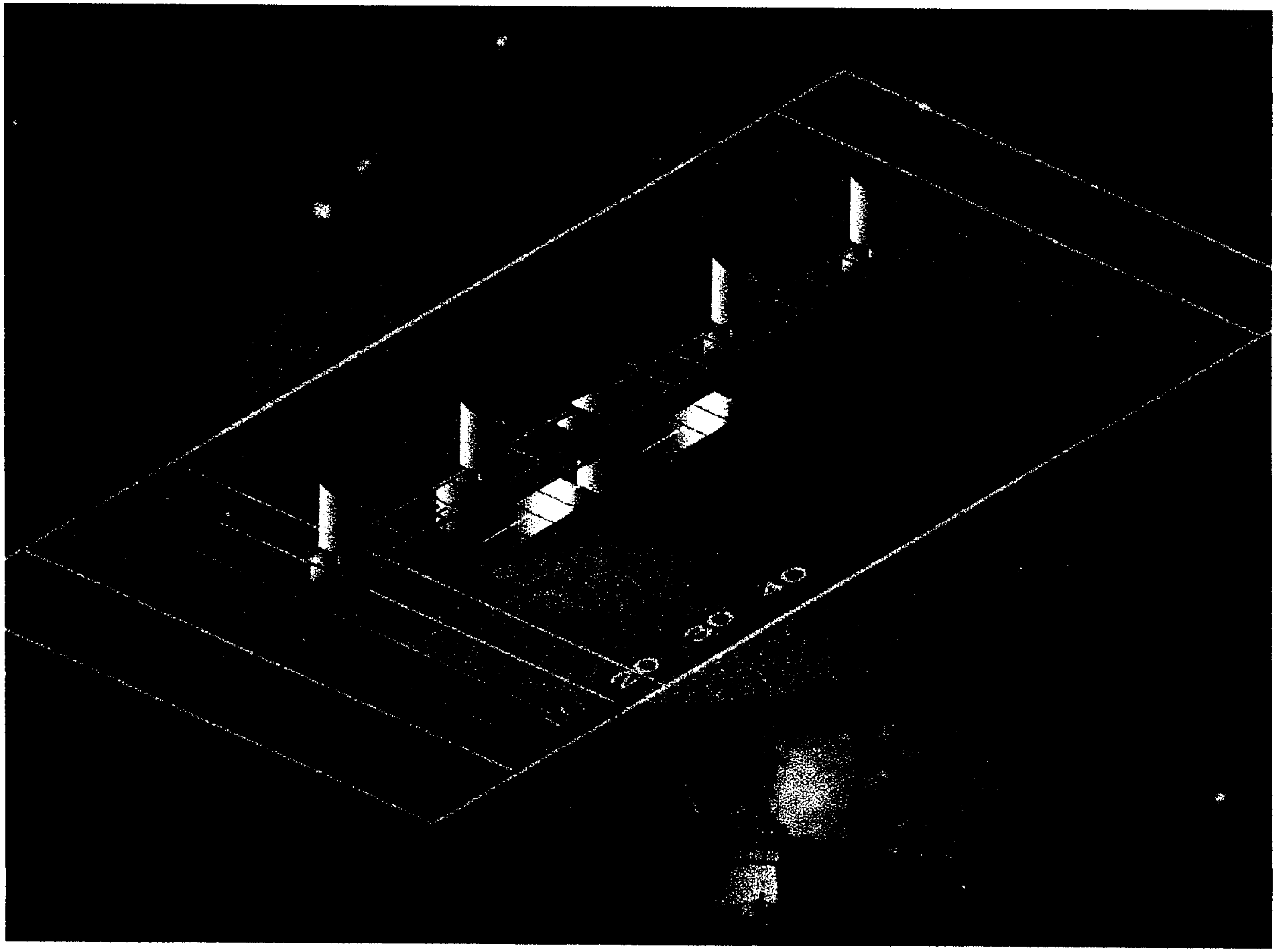


In response as a part of its Origins Program, NASA has planned a series of progressively more capable interferometry missions.



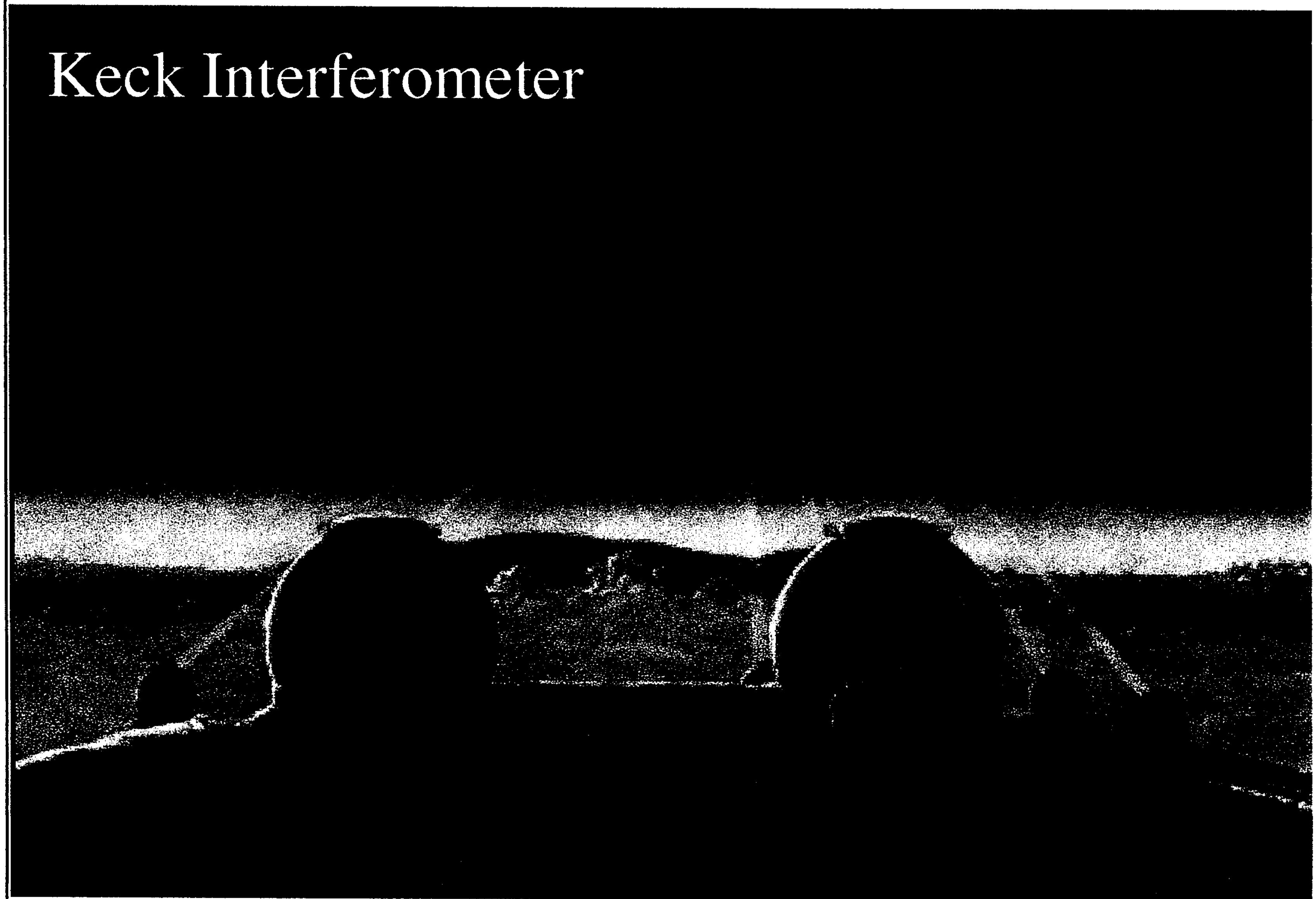
Interferometers –

When Football Field-Sized Telescopes Are Too Prohibitive



ORIGINS

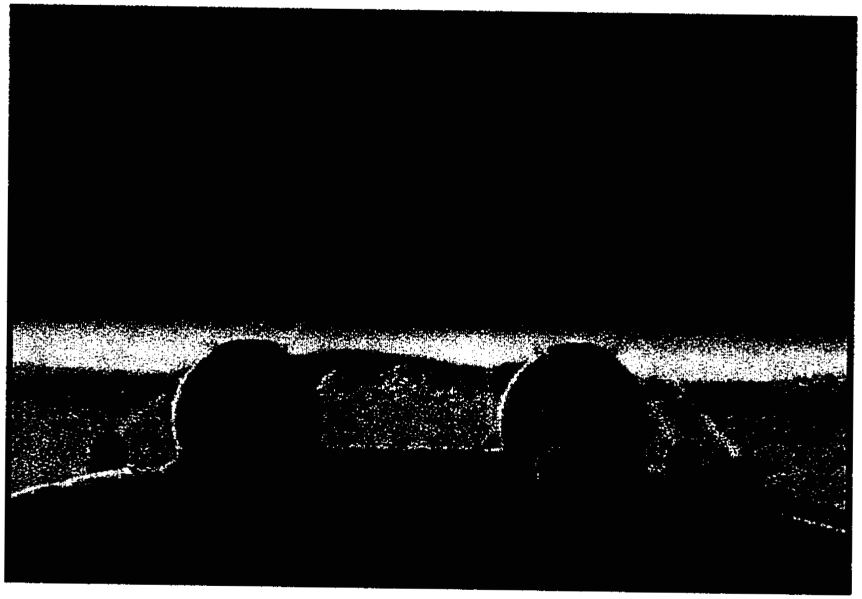
Keck Interferometer



Keck Interferometer

Salient Features

- The two 10-m Keck telescopes + four 2-m class outrigger telescopes
- 85-meter baseline between the two Kecks
- Wavelength: 2 μm and 10 μm
- Imaging resolution: 5 mas at 2 μm
- Astrometric accuracy: 10 μas
- Schedule
  - Two-element: mid-2000
  - Array: mid- 2002

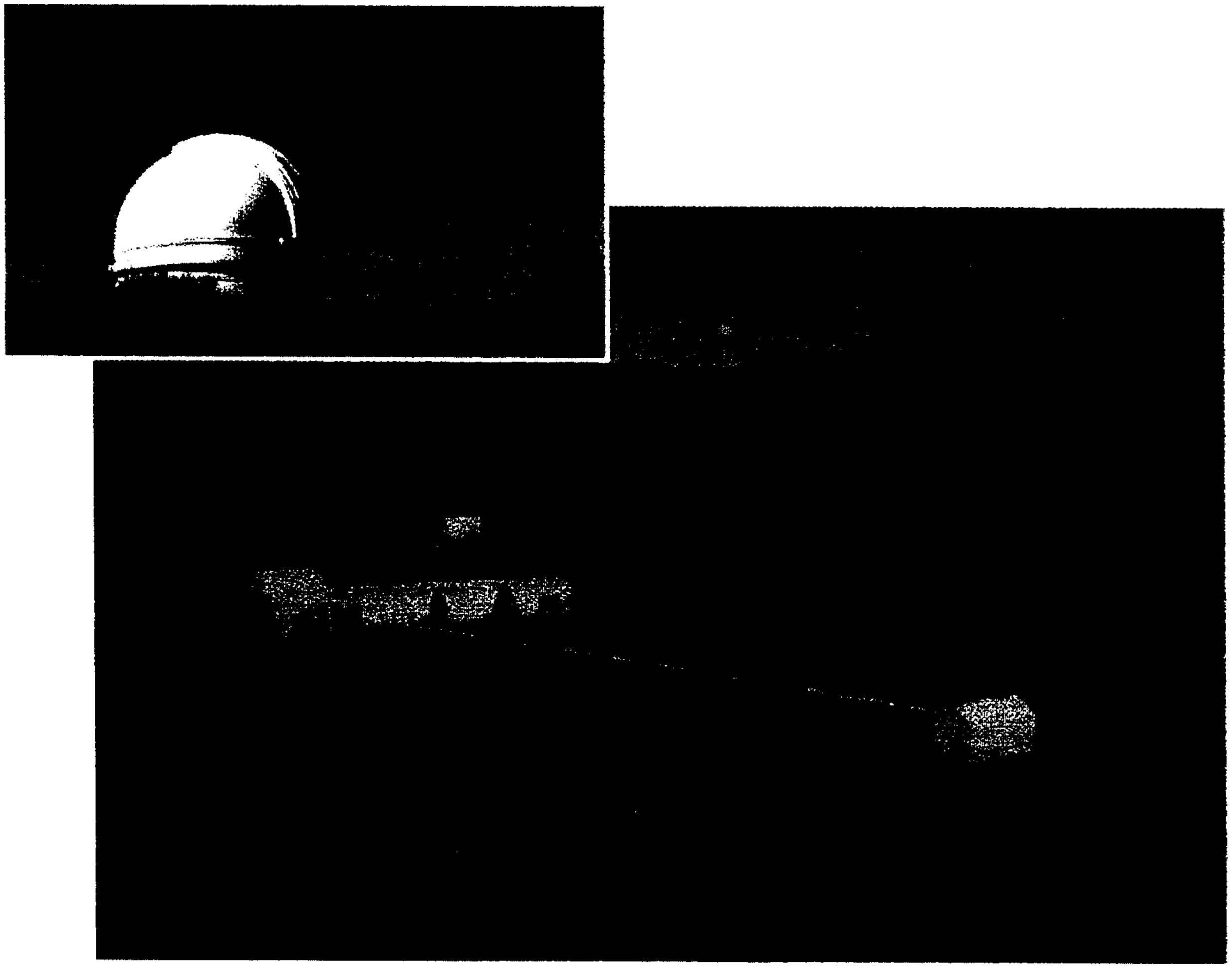


Science

- Direct detection of brown dwarfs and warm Jupiters (Jupiter-mass planets in close orbits)
- Null the star and study zodiacal clouds around nearby stars
  - This data is needed for the TPF design
- Indirect detection of many Uranus-size planets via astrometry
- High-resolution imaging of disks in which planets may be forming

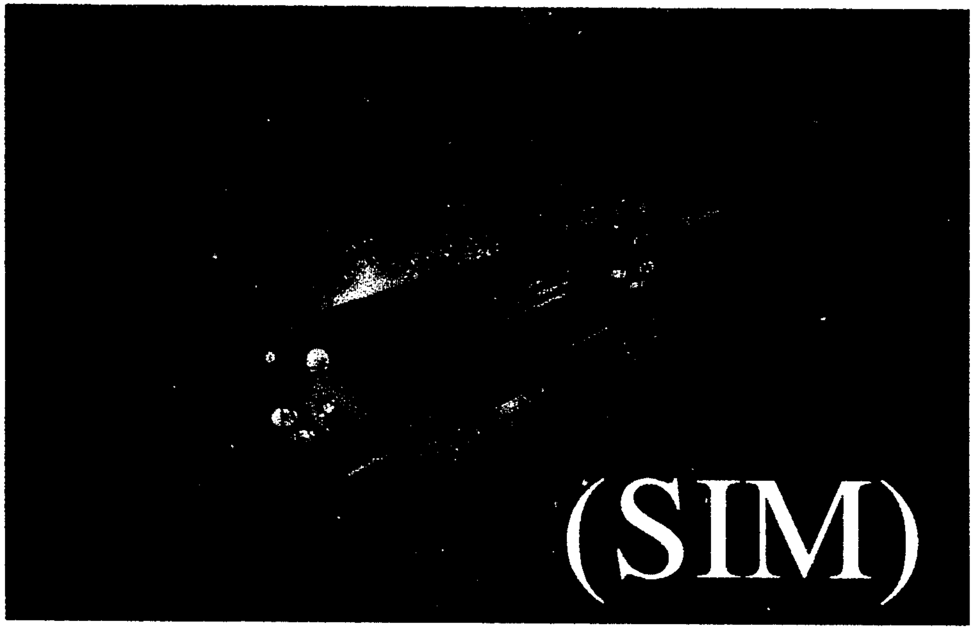
The first two objectives can be met with only the two Kecks connected as an interferometer. The next two require the additional baselines provided by the outrigger telescopes.

Palomar Testbed Interferometer (PTI)



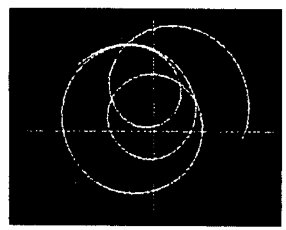
- Testbed for the Keck Interferometer and SIM
- Two baselines
  - N-S & E-W
  - 110 m baseline
- 40 cm aperture
- $\lambda = 2.2\ \mu m$
- Performance
  - 4 mas imaging
  - 100 μas astrom.
- Automated Op.

Space Interferometry Mission

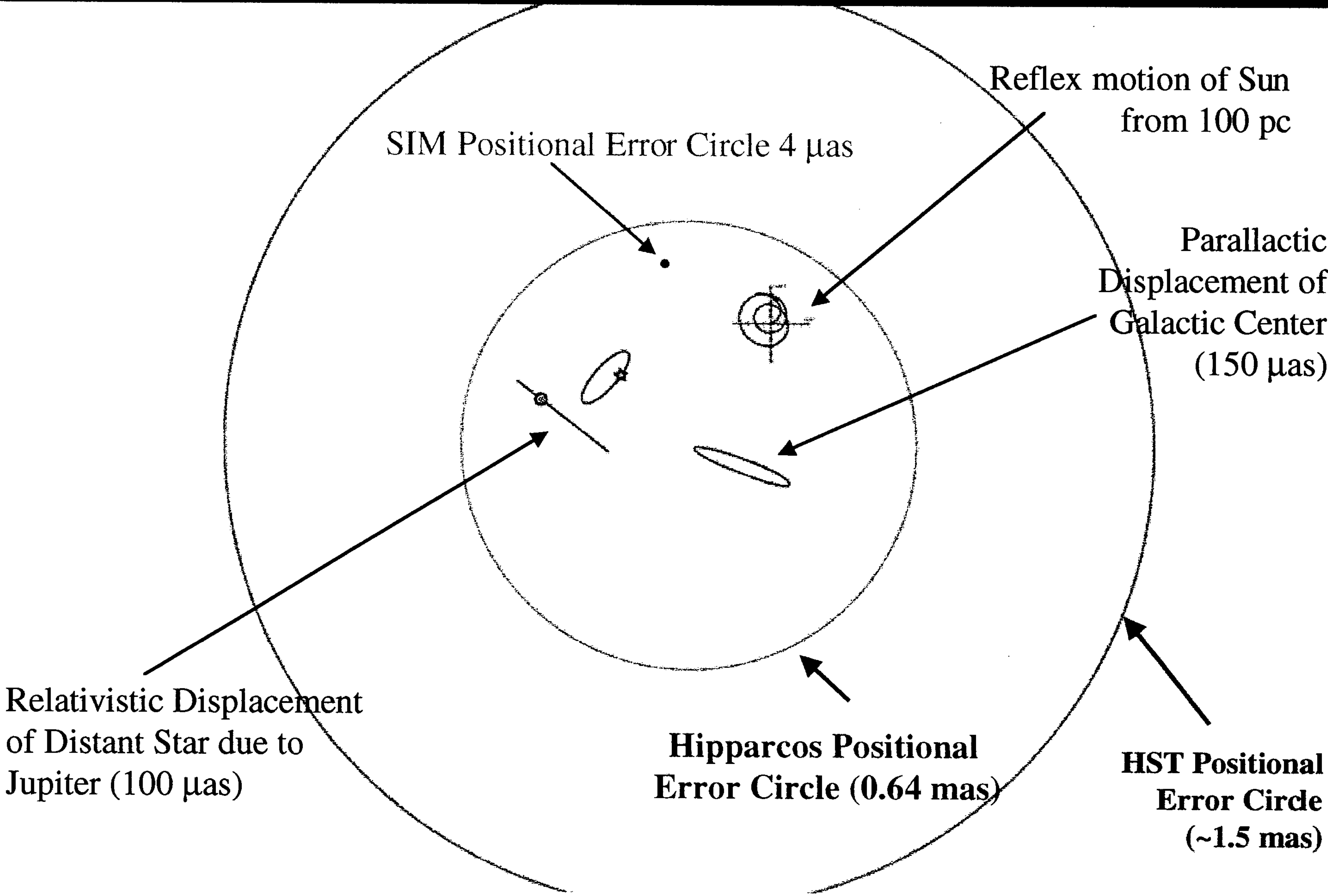


- 10-m Optical Interferometer
- Astrometry
  - 4 μas global
  - 1 μas narrow angle
- Imaging
  - 10 mas
  - 10^{-4} starlight nulling

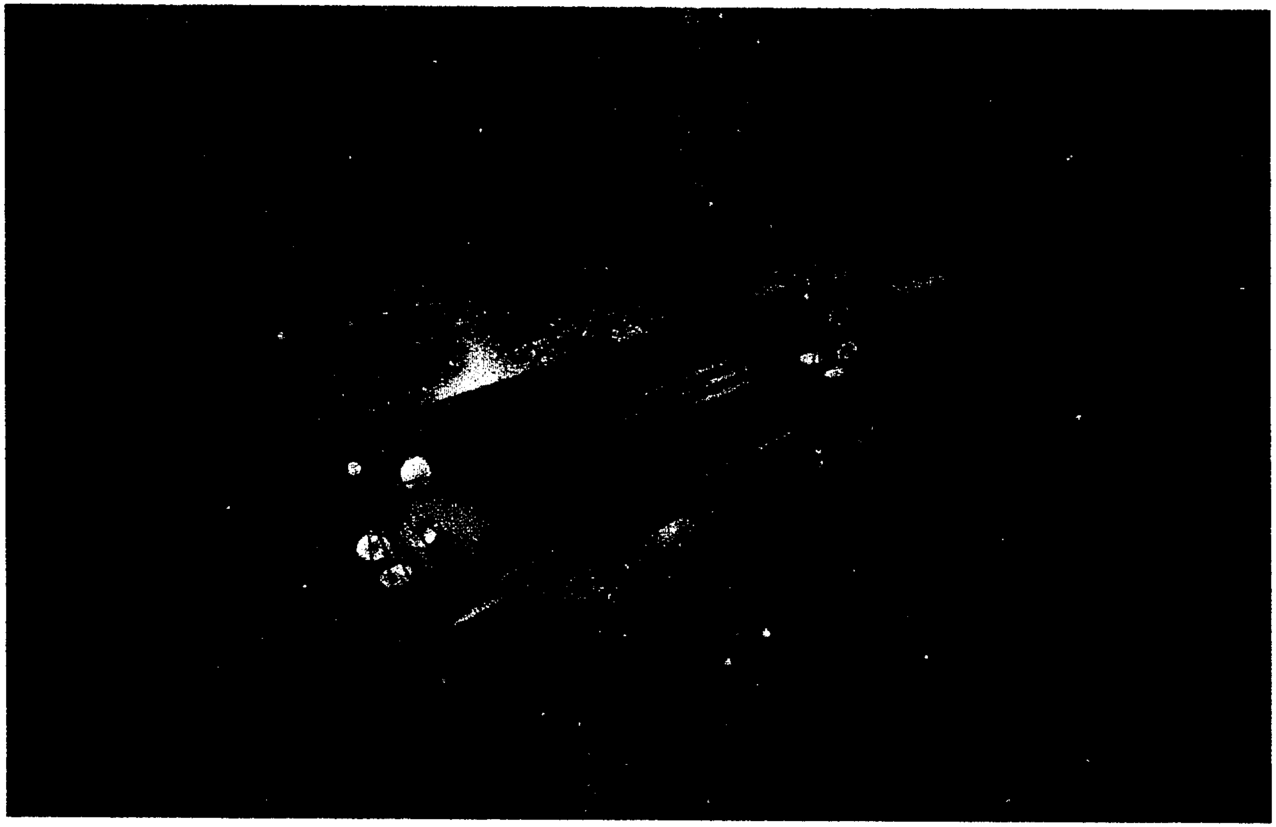
- Looking at the Universe with μ arcsecond precision shows subtleties in the Universe never before detectable



Microarcsecond Precison Opens a New Window to a Multitude of Phenomena Observable with SIM



Key SIM Technologies



Quiet Structures

Nanometer Stability

- *Vibration Isolation*
- *Controlled Optics*

Metrology

Picometer Relative Knowledge

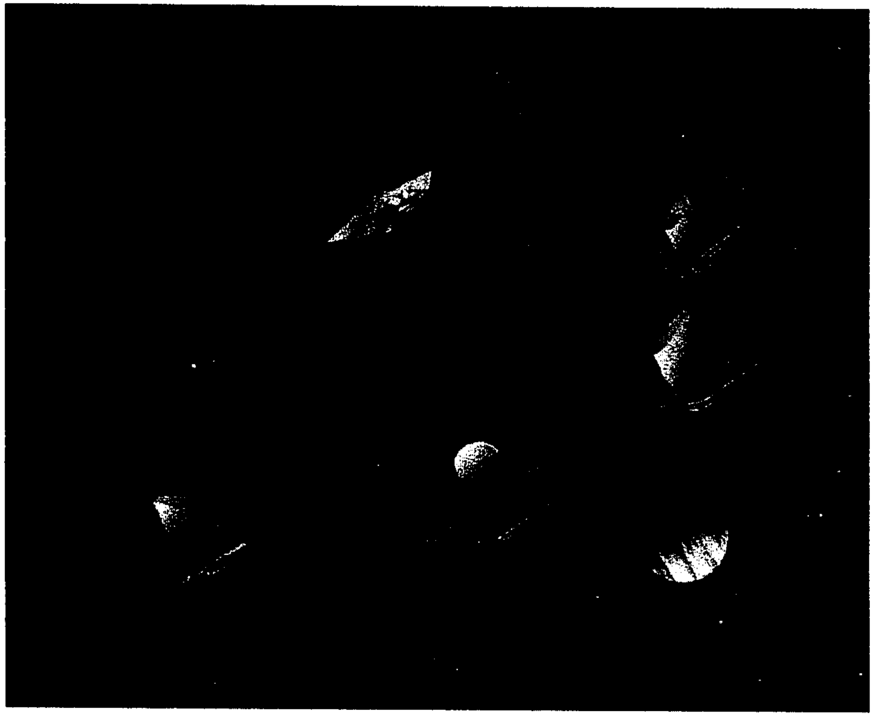
Starlight Nulling

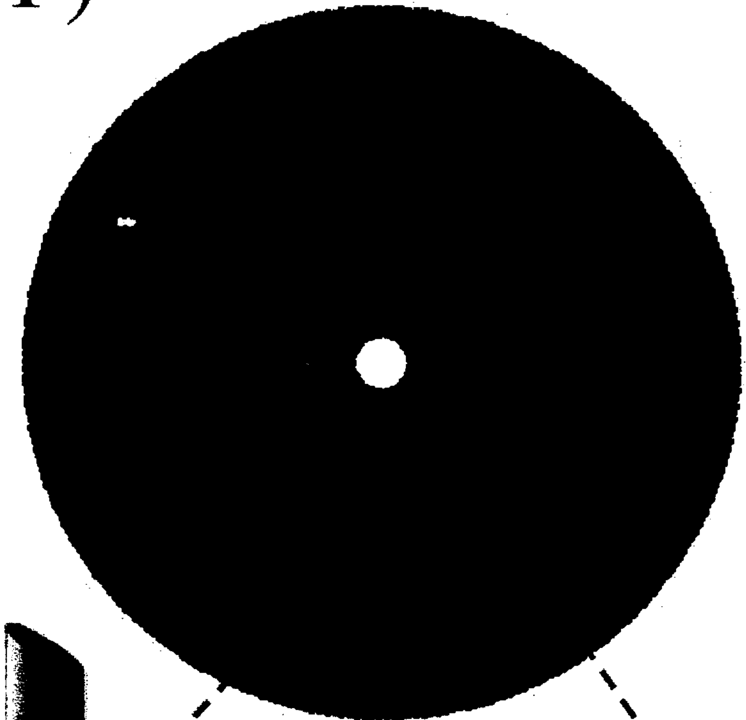
Focal Plane Nulling : (10^{-4})

Interferometer Modeling I &T

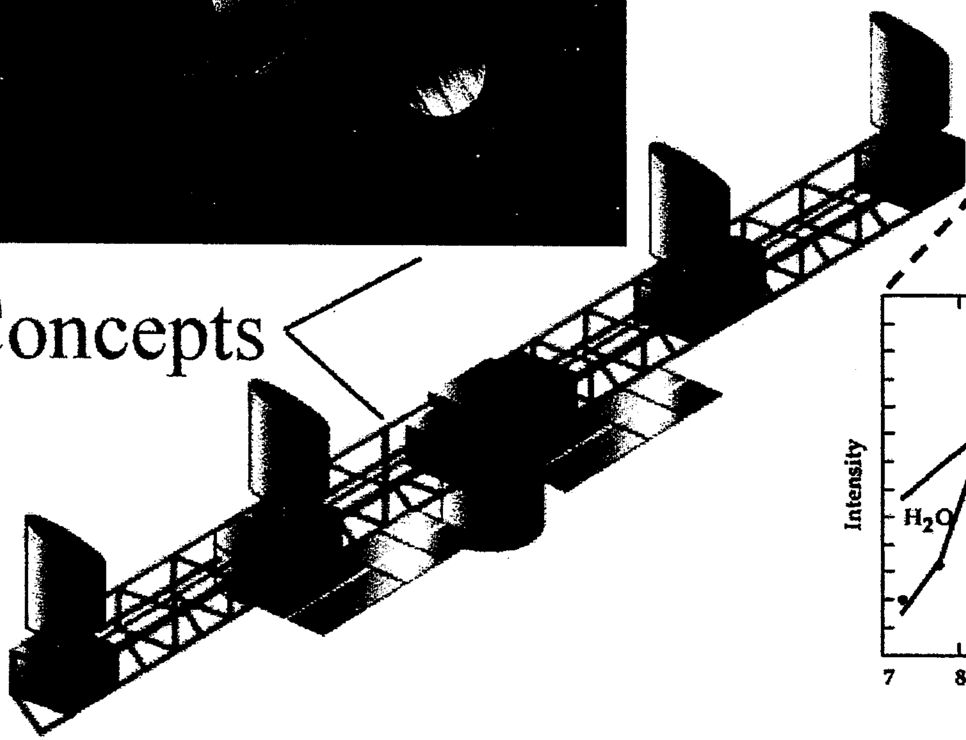
Terrestrial Planet Finder (TPF)

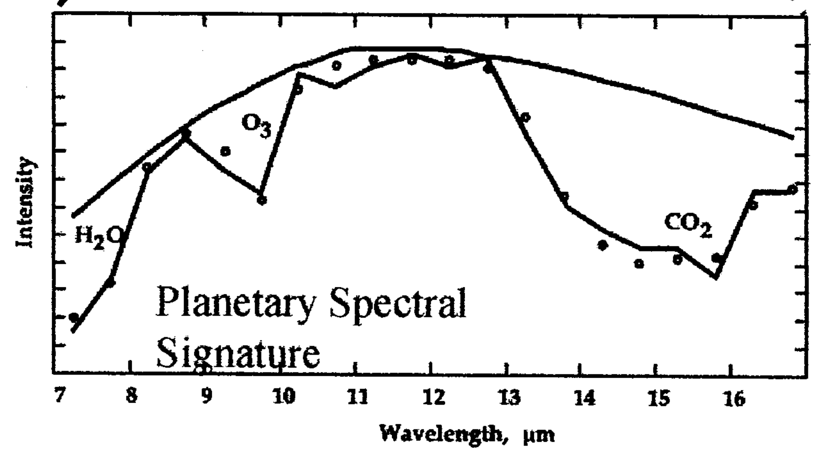
The Search for Earth-Like Planets



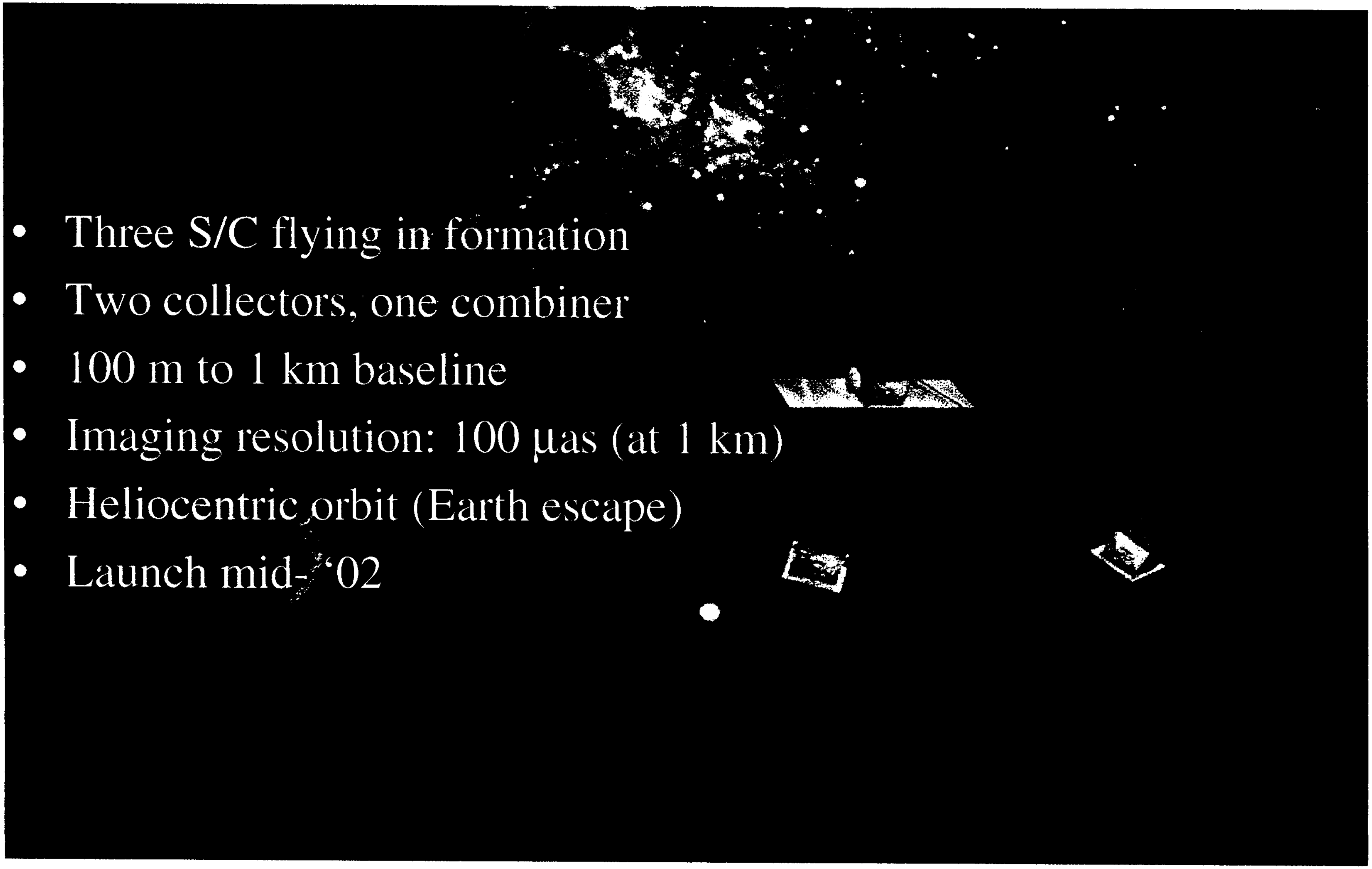


Two Concepts



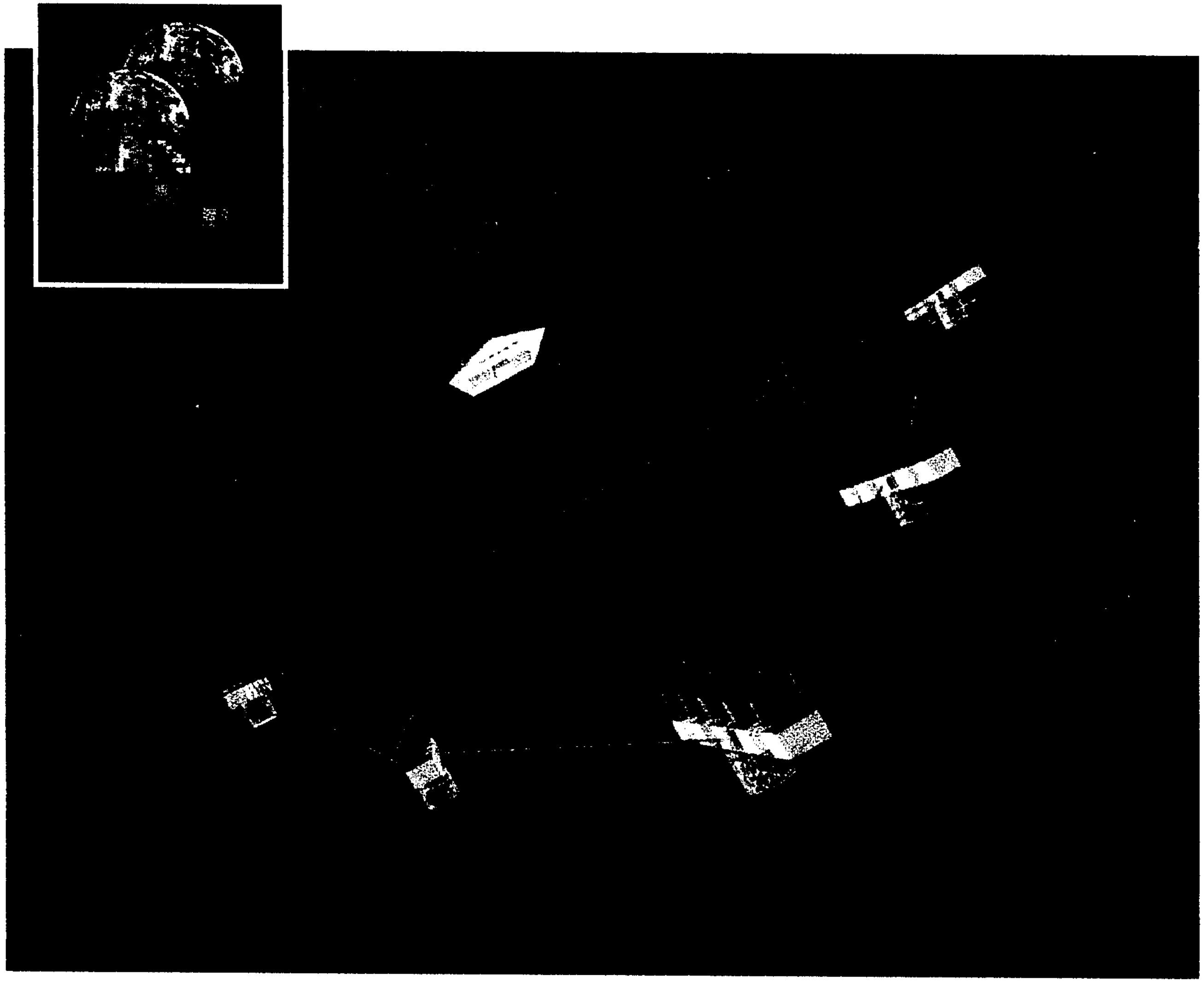


DS-3: Formation Flying Interferometer



Planet Imager

Humanity's First Resolved Images of Another World



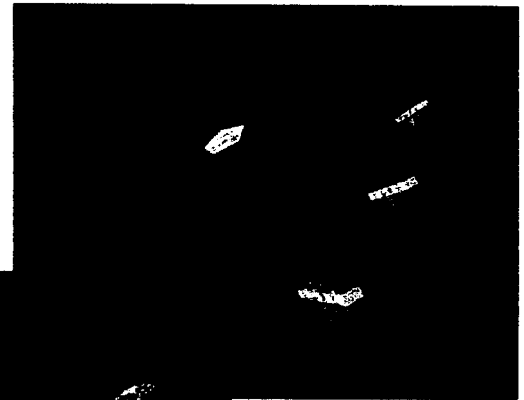
A Concept

- An array of TPF-class interferometers flying in formation
- Starlight nulled at each interferometer and relayed to a beam combiner S/C
- Each interferometer carries four 8-m (NGST class) telescopes to collect starlight and one 8-m teles. to relay collected light to the beam combiner S/C
- Total array baseline: 6000 km
- Total light collecting area: 1000 square meters

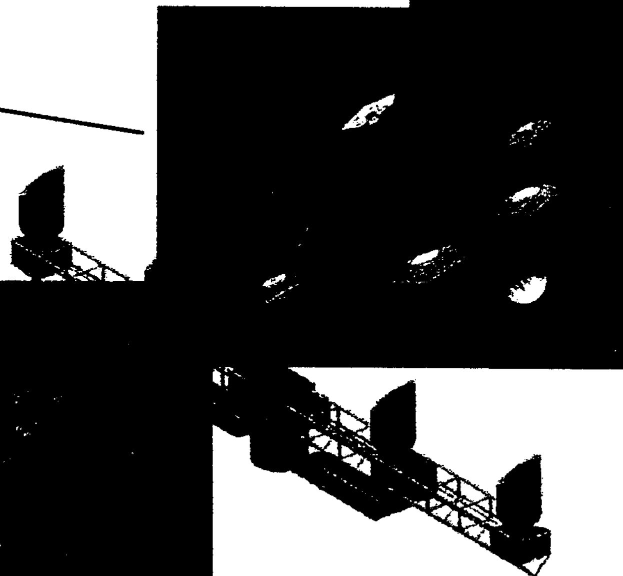
NASA's Interferometers:

Under Development, On the Drawing Board, and Over the Horizon

Planet Imager --2020??

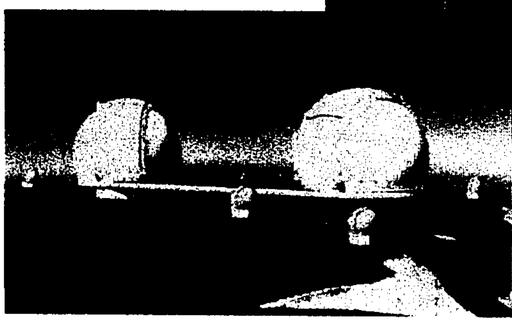


Terrestrial Planet Finder (TPF) -- 2010



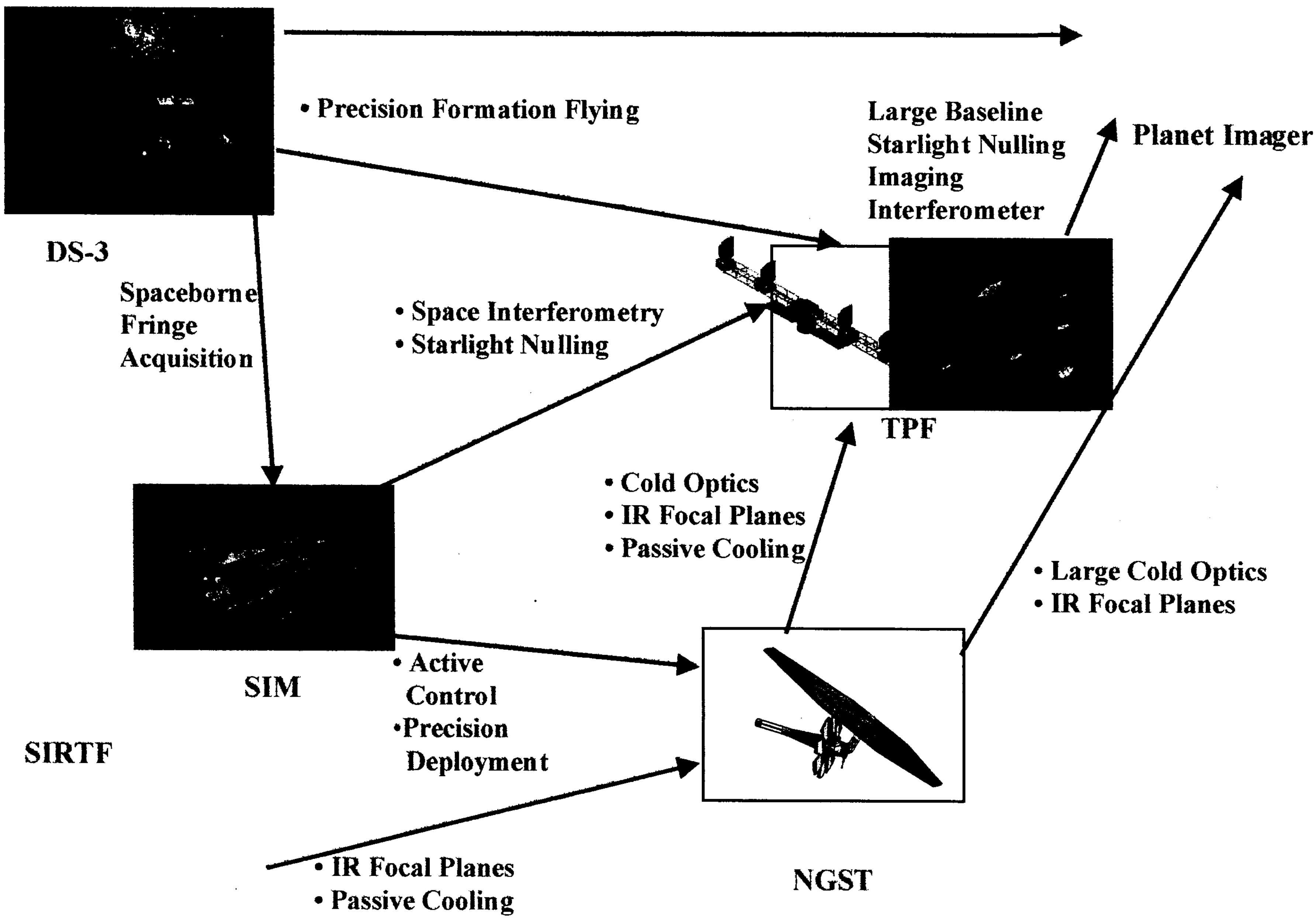
Space Interferometry Mission (SIM) -- 2005

New Millennium Program DS-3 Interferometer -- 2002

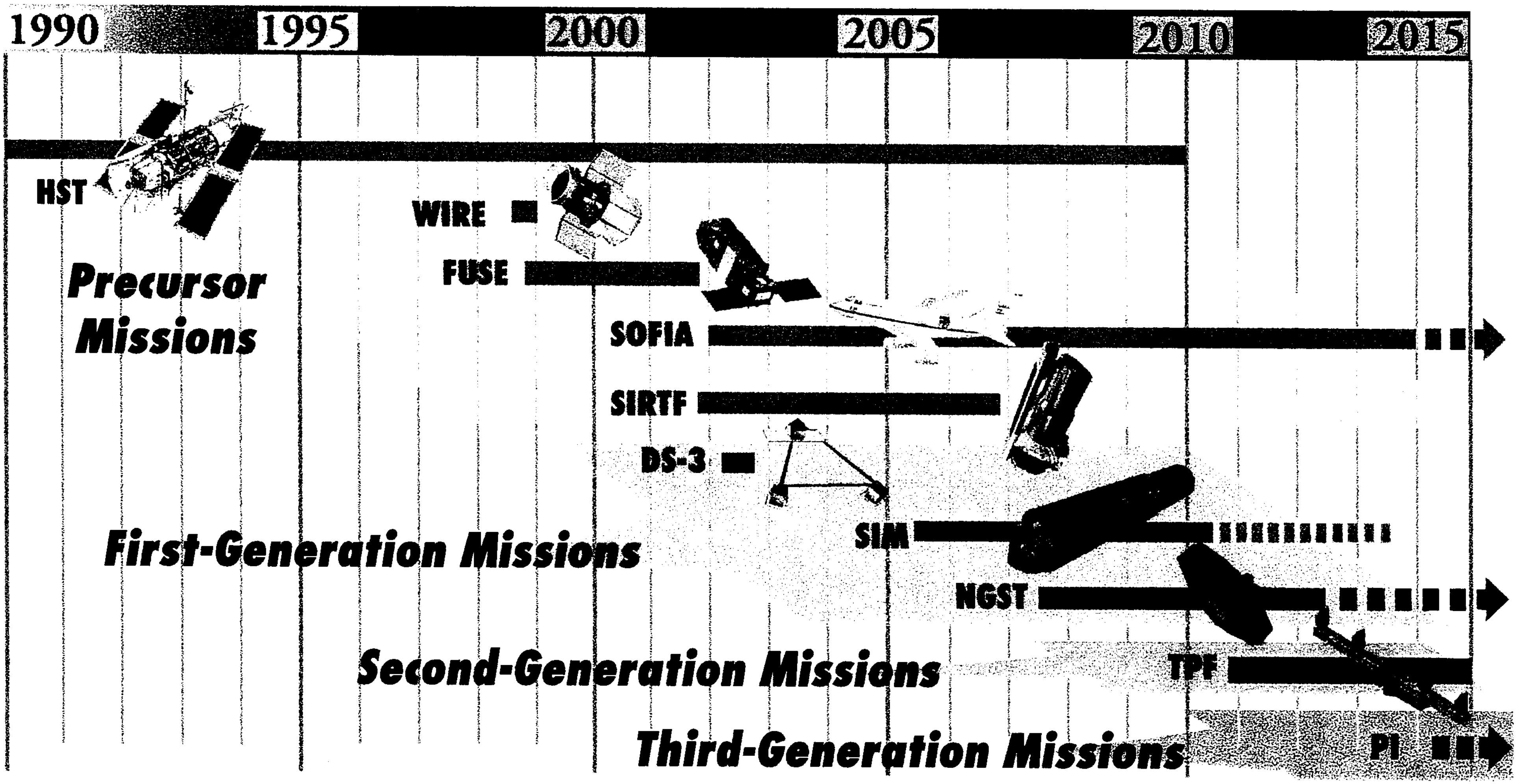


Keck Interferometer -- 2000/2002

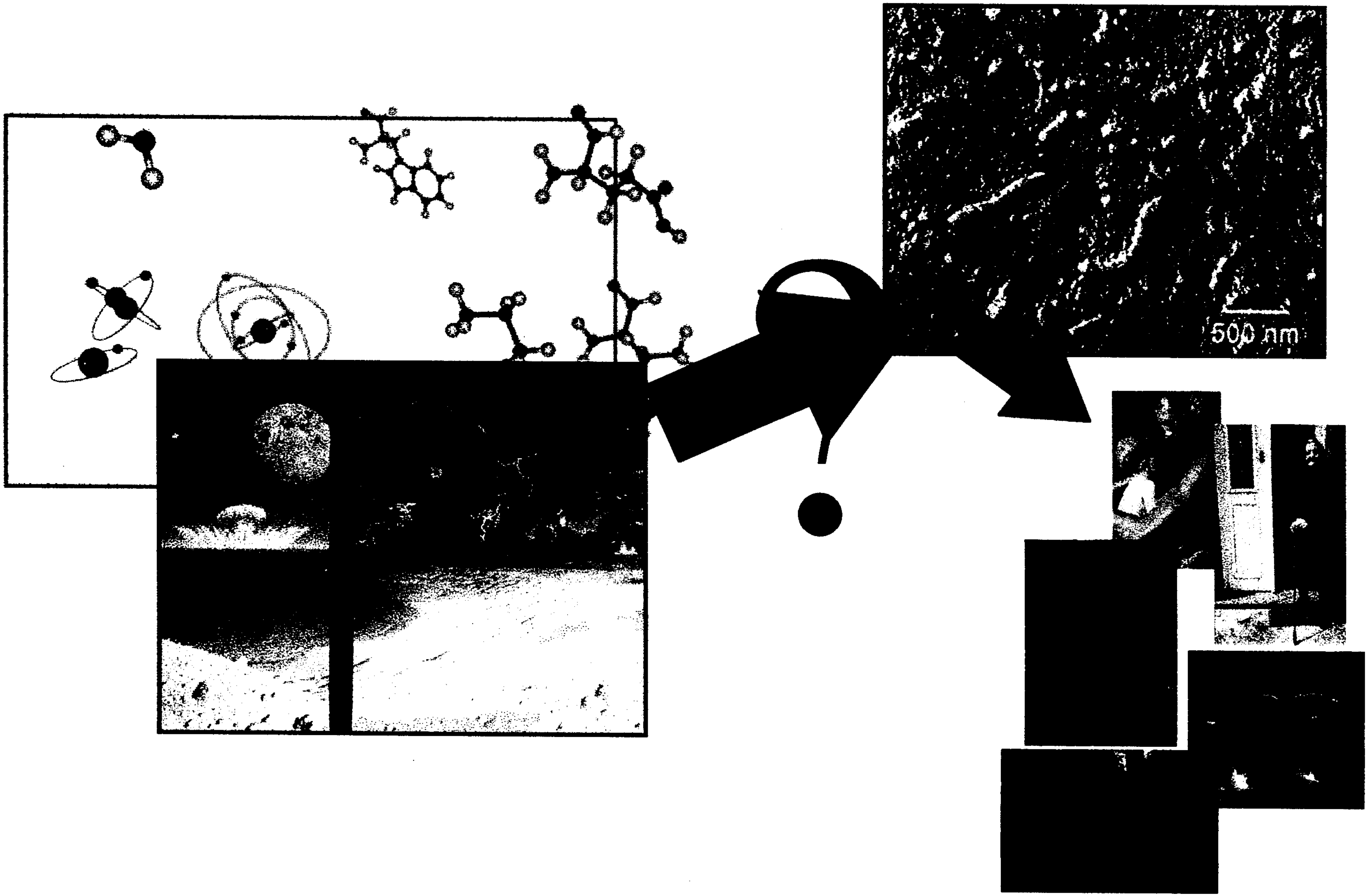
Origins Missions – Technology Flow



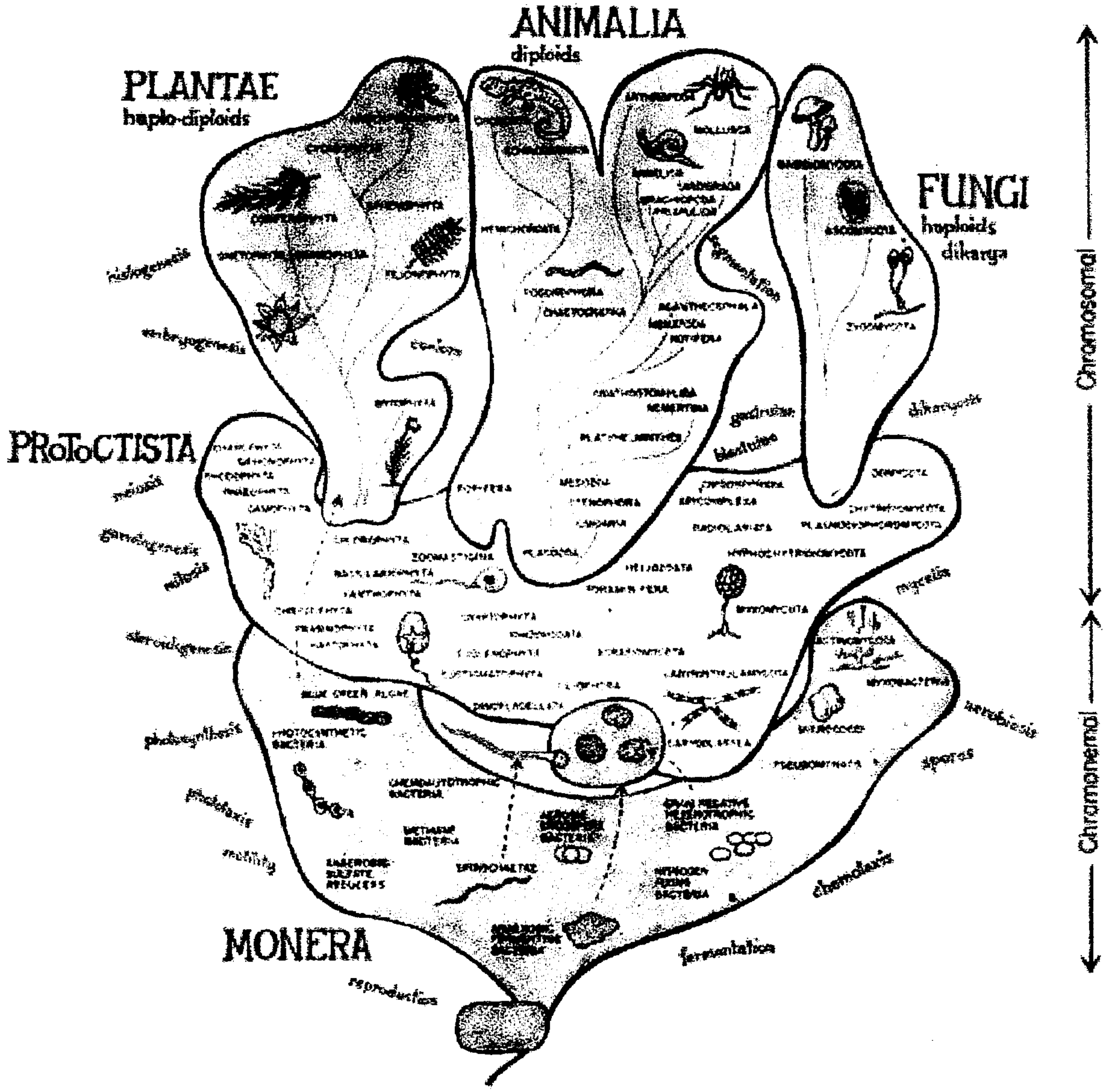
Origins Timeline



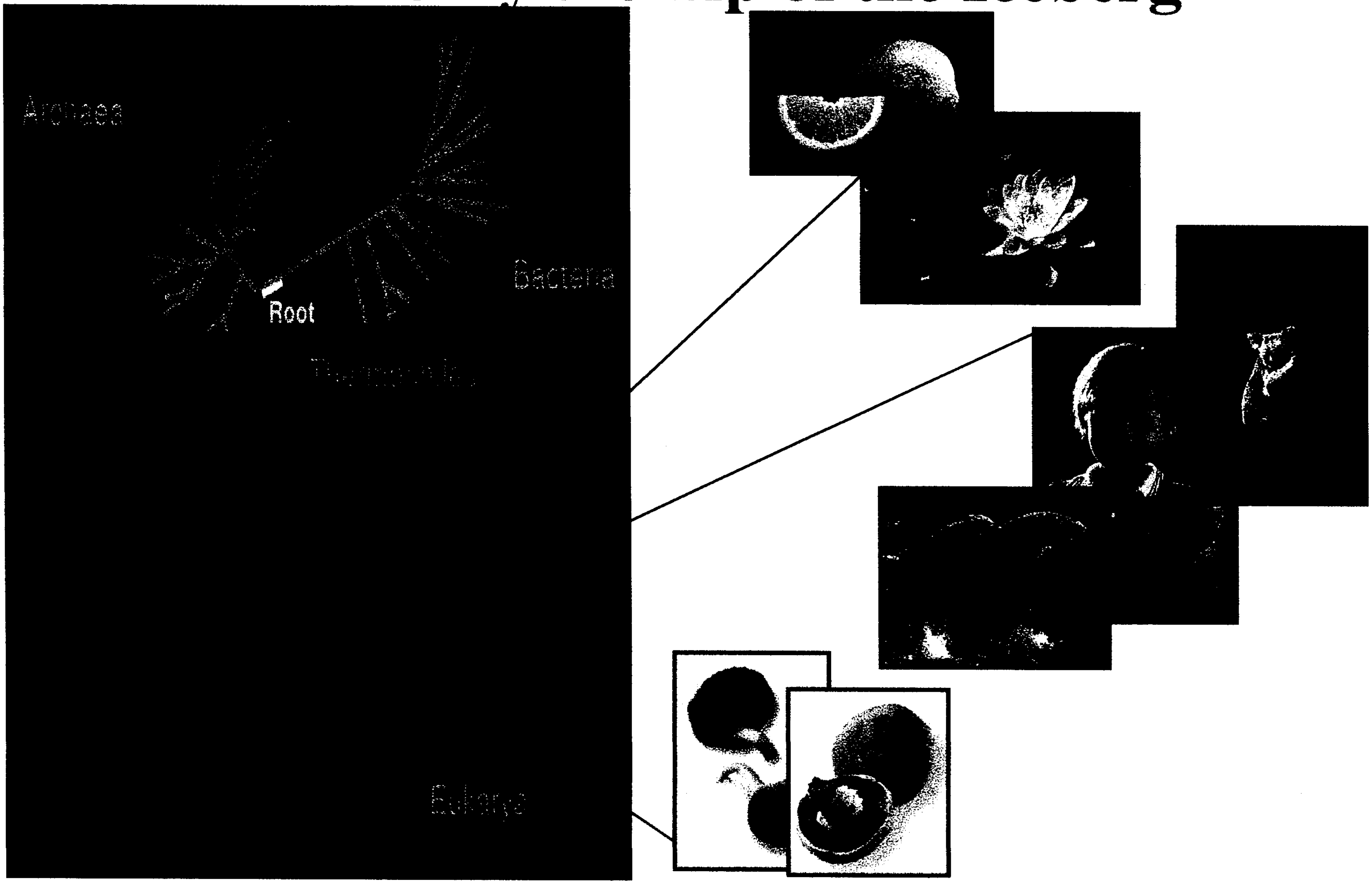
How Did Life Arise on Earth?



A View of Biological Diversity as Late as Two Decades Ago

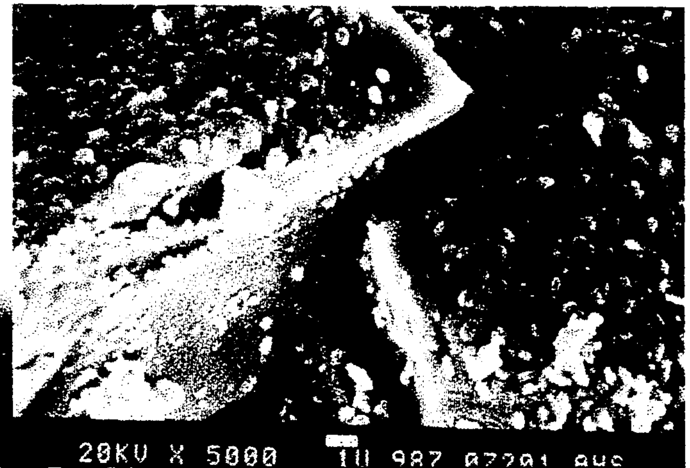


Diversity of Life on Earth
We're Only the Tip of the Iceberg



Life is Hardy

Mount St. Helens



Living Organisms

Too Hot to Handle

Life in Extreme Environments

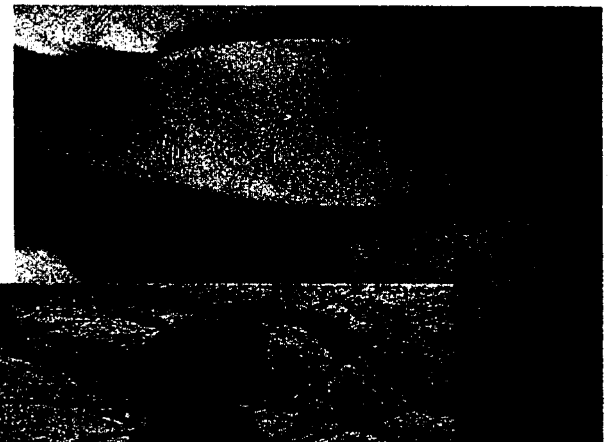
Life on Earth is hardy. It has been found in extreme environments – places previously thought to be far too hot, far too cold, or far too dry

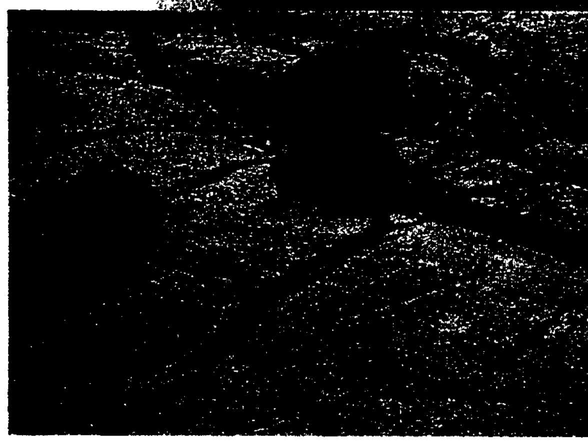
Volcanoes

Icebergs

Hydro-thermal Vents

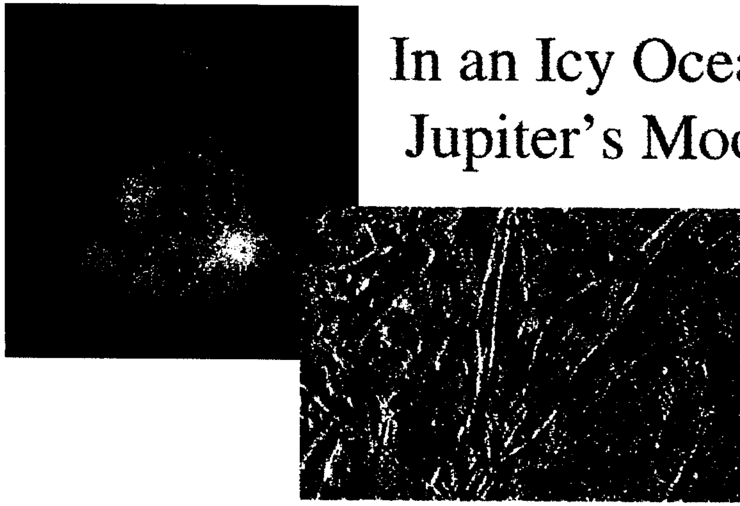
Sand Dunes





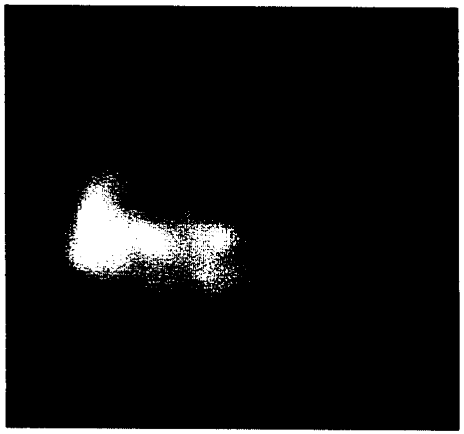
Deep in Rock Crevices

Life Elsewhere in Our Solar System?

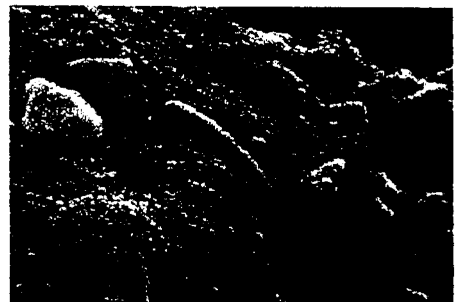


In an Icy Ocean on
Jupiter's Moon, Europa?

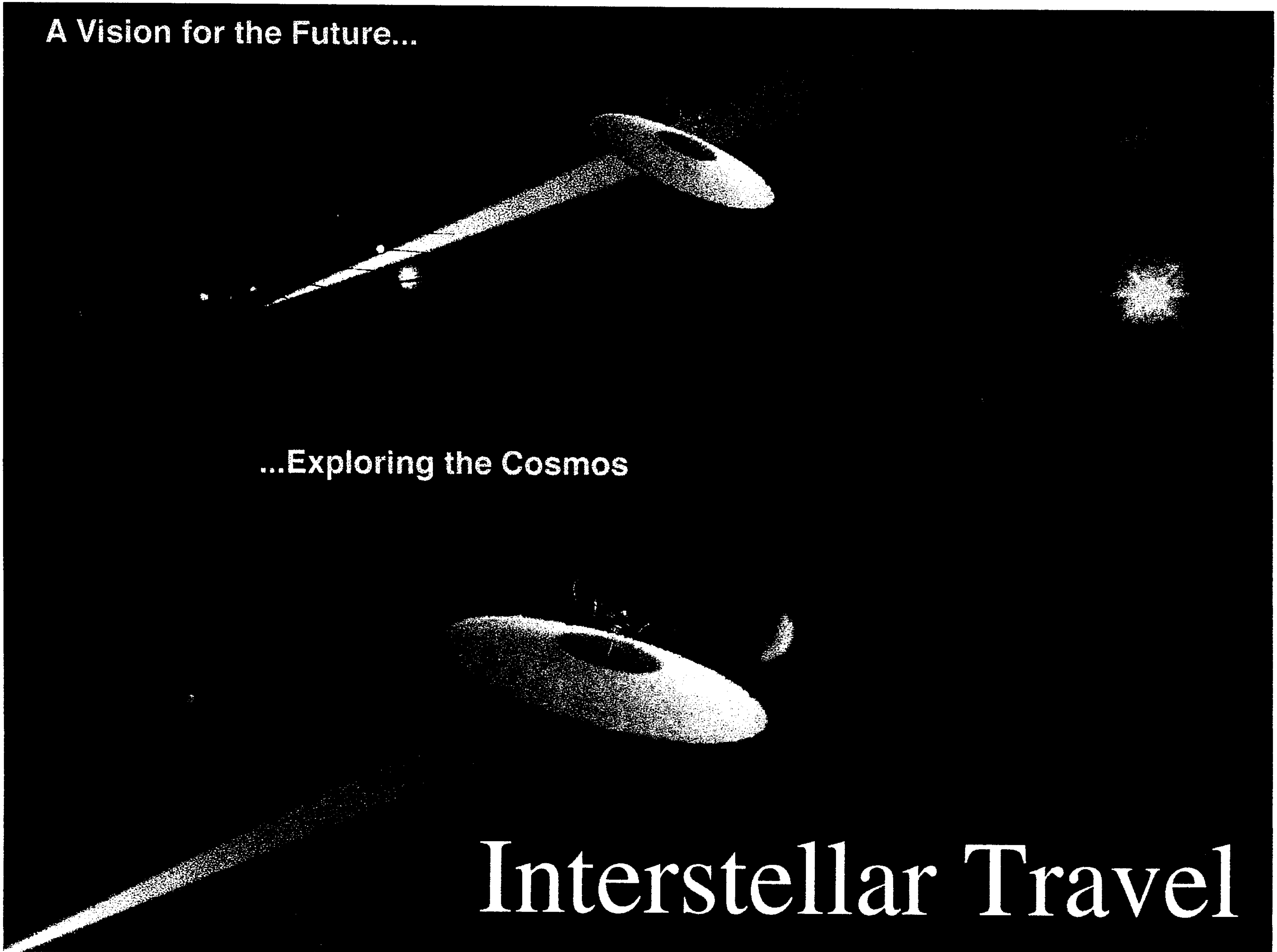
Hidden in Frozen
Rocks on Mars?



What Clues to Pre-biotic
Chemistry Will We Find in
Titan's Atmosphere?



Is This a Fossilized
Martian Organism?


A Vision for the Future...
...Exploring the Cosmos
Interstellar Travel